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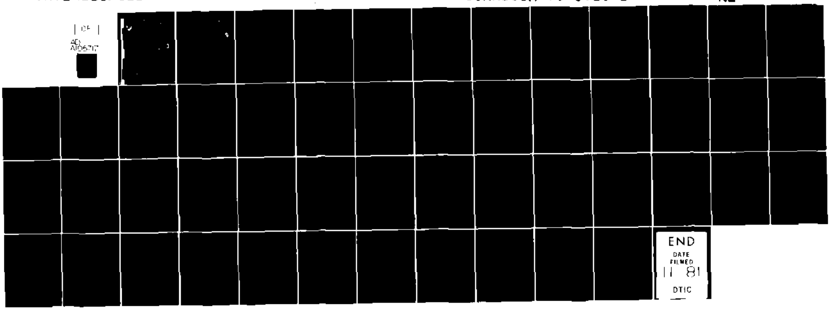

LEVEL III

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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM- 79-0789- 5

MANUFACTURING METHODS AND TECHNOLOGY PROGRAM FOR RUGGEDIZED TACTICAL FIBER OPTIC CABLE

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FIFTH PROGRESS REPORT
FOR PERIOD
JULY 1980 - MARCH 1981

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MANUFACTURING METHODS AND TECHNOLOGY PROGRAM

FOR RUGGEDIZED TACTICAL FIBER OPTIC CABLE

FIFTH PROGRESS REPORT

CONTRACT DAAK80-79-C-0789

For the Period July 1980-March 1981

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Object of Study:
To Establish an Automated Production
Process for Ruggedized Tactical
Fiber Optic Cable

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~~This report covers~~ the period from July 1980 through March 1981 of the manufacturing methods and technology program for ruggedized tactical fiber optic cable. The scope of this effort, as reported herein, includes the following tasks and achievements:

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20. (continued)

a. Cable process optimization

(1) Produce trial runs of confirmatory samples.

(2) Complete lay length samples (two lays).

(3) Perform optical and mechanical tests on trial confirmatory samples.

(4) Produce samples and evaluate polyurethanes (three types)

b. Use of facilities

(1) Operate high speed strander, Kevlar® braider, and extruder at production speeds.

c. Secondary performance

(1) Evaluate low temperature performance.

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SUMMARY

This report covers the period from July 1980 to March 1981 of the manufacturing methods and technology (MM&T) program for ruggedized tactical fiber optic cable. In this time frame, a high numerical aperture (NA) fiber need was identified and the fiber produced; the production rate was achieved for the cabling equipment using MM&T materials; the cabling effects on the fiber properties were evaluated; a degradation in performance of polyurethane was traced to processing changes by the manufacturer, so a polyurethane evaluation was conducted; low temperature optical effects were studied; and a significant improvement in the test station was achieved. The result of this work is that a set of guidelines for production handling of fibers for optimum performance has been outlined, a window of polyurethane properties has been identified, and development of a suitable compound is continuing. The schedule was adjusted to accommodate the added scope of developing low temperature fiber performance.

PREFACE

The purpose of this MM&T program is to establish automated production processes for ruggedized tactical fiber optic cables in accordance with Specification MMT-789898 dated 2 February 1978 with Revision 1 dated 1 August 1980 and ECIPPR No 15.

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1.0 INTRODUCTION

This document describes the results of the MM&T cable development, fiber and materials evaluation, production processes, temperature performance development, and MIL-Q-9858A documentation performed between July 1980 and March 1981 under this contract. The purpose of this contract is to establish automated production processes for ruggedized tactical fiber optic cables. In the period covered by reports 1 through 4, the initial stages of cable fabrication, facilities operation, and materials evaluation were covered. In this report, the first attempt at fabrication of the engineering samples; testing of production rates for the high speed strander, fiber serving line, and jacket extrusion lines; and evaluation of the test stations are described. During the course of the preliminary studies, it was requested that low temperature performance be monitored. As a result, it was determined that the lower NA fibers did not give suitable attenuation performance at low temperature. Additionally, it was discovered that previously satisfactory polyurethane did not meet performance requirements as a result of formula and processing changes made when the product line was purchased by another manufacturer. As a result, studies of low temperature attenuation performance, development of higher NA fibers, and evaluations of replacement polyurethanes were undertaken. These efforts, which were beyond the original scope of the contract for establishing automated cable production processes, were accommodated with a schedule revision.

The goals for the next period are to complete the polyurethane and fiber evaluations, incorporate the design into the final engineering samples, and confirm performance level testing. The MIL-Q-9858A documentation is also expected to be completed.

2.0 TEST SAMPLE FABRICATION

Test samples were fabricated to confirm the production method and cable design. The considerations implemented were cable construction optimization, operational speeds, materials, and cabling losses in constructing the cable. The properties were evaluated in separate trial runs. Figure 2.0-1 shows the cable configuration fabricated.

2.1 Cable Construction Optimization

The following properties were evaluated in determining the optimum cable design:

a. Producibility

b. Optical properties

c. Mechanical properties

The criterion used in producibility was minimum fabrication time required to produce each construction consistent with a quality product. The quality was evaluated by the mechanical tests of the cable and the optical properties of the fiber.

2.2 Confirmatory Phase Cable Fabrication

A total of 10 cables was fabricated using fibers evaluated in 1100 m increments. The fibers used in this phase were obtained from standard production with lower NAs (approximately 0.23 at 90% power) and required buffering with Hytrel® off-line over the silicone room temperature vulcanizing (RTV) silicone buffer. The

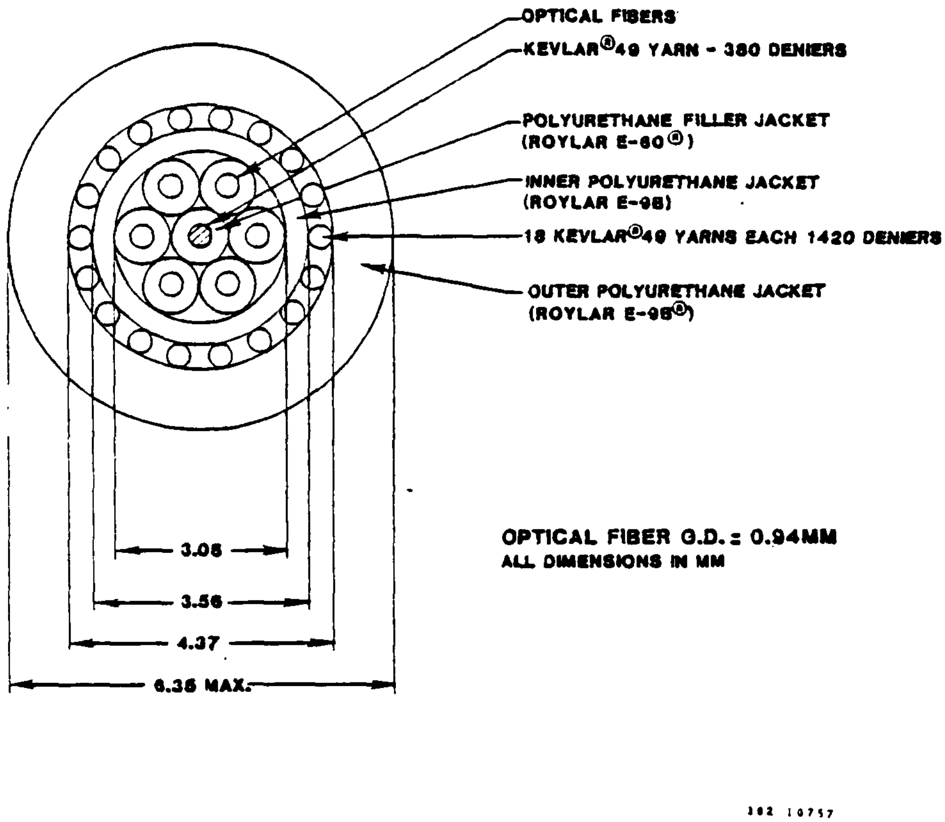

Figure 2.0-1. Basic MM&T Cable Design.

finished cables had marginal or unacceptable performance as indicated in Tables 2.2-1 through 2.2-6.

The results from these cables indicate that standard production fibers are not suitable for military type applications and that higher injection NA (approximately 0.25) fibers with consistent performance will be required. A complete effort to address these issues has been initiated on internal funding.

2.3 Polyurethane Evaluation

The initial samples were fabricated using Roylar® E-80 supplied by Uniroyal Chemical, Inc. This company sold its trade name and product line to B. F. Goodrich. ITT EOPD evaluated the compound produced by B. F. Goodrich (its new name is Estane® 58880) and found that its performance differed from Uniroyal's Roylar® E-80.

In order to evaluate the deviations, two samples of Estane® 58880 were procured and extruded onto cables for tests.

The comparison of the original E-80 with two B. F. Goodrich samples is shown in Table 2.3-1 (Estane® 4054 is a laboratory batch number for Estane® 58880; BL-4 and BL-19 show two different melt indexes.)

Table 2.2-1. General MM&T Cable Results.

Cable #1 120380-4c-1a, 1249 m	Attenuation marginal, 4.82 dB/km
Cable #2 120380-4c-1b, 844 m	Length short due to fiber break on high speed strander
Cable #3 120380-4c-2, 1105 m	Dispersion high, 2.46 ns/km
Cable #4 120380-4c-3, 1022 m	Attenuation high, 5.73 dB/km
Cable #5 012181-4c-1, 1100 m	Fiber broke twice due to high speed strander malfunction
Cable #6 012181-4c-2, 1105 m	Attenuation high, 5.14 dB/km
Cable #7 012181-4c-3, 981 m	Length short, extrusion difficulty from poor E-80
Cable #8 012181-4c-4, 1081 m	Attenuation and dispersion marginal, 4.90 dB/km and 1.90 ns/km
Cable #9 012181-4c-5, 1101 m	Attenuation high, 5.14 dB/km
Cable #10 012181-4c-6, 1095 m	Dispersion high, 2.17 ns/km

Table 2.2-2. Cable Results, Cables #1 and #2.

CABLE #1
120380-4c-1a, 1249 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	3.93	3.78	-0.15	0.29	0.57	+0.28	0.66	0.48
2) White	3.52	3.71	+0.19	0.97	0.95	-0.02	1.01	0.50
3) Blue	3.64	3.82	+0.18	0.97	1.84	+0.87	0.52	0.18
4) White	3.70	4.69	+0.99	0.45	0.96	+0.51	2.69	1.89
5) White	4.53	4.82	+0.29	1.22	0.78	-0.44	4.77	21.88
6) White	3.65	3.58	-0.07	1.18	0.66	-0.52	4.51	5.04
AVERAGE	3.83	4.07	+0.24	0.85	0.96	+0.11		

CABLE #2
120380-4c-1b, 844 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	3.93	3.82	-0.11	0.29	.84	+0.55	0.66	-
2) White	3.52	3.55	+0.03	0.97	1.27	+0.30	1.01	-
3) Blue	3.64	3.76	+0.12	0.97	1.97	+1.00	0.52	-
4) White	3.70	4.01	+0.31	0.45	1.03	+0.58	2.69	-
5) White	4.53	4.03	-0.50	1.22	1.32	+0.10	4.77	-
6) White	3.65	2.56	-1.09	1.18	.84	-0.34	4.51	-
AVERAGE	3.83	3.62	-0.21	0.85	1.21	+0.36		

Table 2.2-3. Cable Results, Cables #3 and #4.

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	ATTENUATION (dB/KM) AFTER	ATTENUATION (dB/KM) Δ	DISPERSION (NS/KM) BEFORE	DISPERSION (NS/KM) AFTER	DISPERSION (NS/KM) Δ	ATTEN. INCREASE @ -55°C FIBER	ATTEN. INCREASE @ -55°C CABLE
CABLE #3 120380-4c-2, 1105 Meters								
1) Red	3.28	-	-	1.07	.57	-0.50	0.85	-
2) White	3.52	-	-	0.97	1.05	+0.08	1.01	-
3) Blue	3.42	-	-	1.41	2.46	+1.05	1.86	-
4) White	3.70	-	-	0.45	1.95	+1.50	2.69	-
5) White	4.53	-	-	1.22	1.71	+0.49	4.77	-
6) White	3.65	-	-	1.18	.69	-0.49	4.51	-
AVERAGE	3.68	-	-	1.05	1.41	+0.36		
CABLE #4 120380-4c-3, 1022 Meters								
1) Red	4.59	3.59	-1.00	0.64	1.26	+0.62	3.09	1.16
2) White	3.06	4.06	+1.00	1.56	1.08	-0.48	0.35	1.05
3) Blue	3.23	3.53	+0.30	0.87	1.57	+0.70	5.00	1.19
4) White	4.20	5.73	+1.53	0.90	0.60	-0.30	0.59	1.05
5) White	3.93	3.86	-0.07	0.77	1.46	+0.69	1.47	25.21
6) White	4.65	3.82	-0.83	0.60	0.72	+0.12	3.12	14.58
AVERAGE	3.94	4.10	+0.16	0.89	1.12	+0.23		

Table 2.2-4. Cable Results, Cables #5 and #6.

CABLE #5
012181-4c-1, 1100 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	3.38	-	-	0.77	1.58	+0.81	4.22	-
2) White	3.48	-	-	1.30	1.33	+0.03	5.13	-
3) Blue	3.71	-	-	1.35	*	*	-	-
4) White	3.96	-	-	0.78	.52	-0.26	2.32	-
5) White	3.69	-	-	1.11	1.01	-0.10	1.05	-
6) White	3.81	-	-	0.52	.45	-0.07	2.32	-
AVERAGE	3.67	-	-	0.97	0.98	+0.01		

CABLE #6
012181-4c-2, 1105 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	3.92	4.01	+0.09	1.32	1.69	+0.37	1.13	-
2) White	3.48	4.45	+0.97	1.30	1.27	-0.03	5.13	-
3) Blue	3.97	4.82	+0.85	0.99	0.67	-0.32	-	-
4) White	3.56	3.48	-0.08	1.20	0.84	-0.36	1.05	-
5) White	3.70	5.14	+1.44	0.58	0.71	+0.13	-	-
6) White	3.06	4.03	+0.97	1.51	1.06	-0.45	1.91	-
AVERAGE	3.62	4.32	+0.70	1.15	1.04	-0.11		

*DOES NOT TRANSMIT

Table 2.2-5. Cable Results, Cables #7 and #8.

CABLE #7
012181-4c-3, 981 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	3.99	-	-	1.09	-	-	3.09	-
2) White	3.90	-	-	0.70	-	-	-	-
3) Blue	4.35	-	-	0.81	-	-	-	-
4) White	3.48	-	-	1.50	-	-	1.89	-
5) White	3.61	-	-	1.38	-	-	1.94	-
6) White	3.73	-	-	1.58	-	-	4.92	-
AVERAGE	3.84	-	-	1.18	-	-		

CABLE #8
012181-4c-4, 1081 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	3.56	3.77	+0.21	1.40	0.80	-0.60	3.36	-
2) White	3.92	4.27	+0.35	1.77	1.45	-0.32	1.27	-
3) Blue	4.41	4.90	+0.49	0.98	0.68	-0.30	-	-
4) White	3.73	4.16	+0.43	1.51	0.57	-0.94	1.89	-
5) White	3.31	4.04	+0.73	1.69	0.73	-0.96	0.55	-
6) White	4.14	4.79	+0.65	1.60	1.90	+0.30	1.47	-
AVERAGE	3.85	4.32	+0.47	1.49	1.02	-0.47		

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Table 2.2-6. Cable Results, Cables #9 and #10.

CABLE #9
012181-4c-5, 1101 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	4.23	4.80	+0.57	0.97	1.07	+0.10	2.67	-
2) White	4.29	4.15	-0.14	0.69	1.11	+0.42	-	-
3) Blue	4.49	5.14	+0.65	1.56	1.50	-0.06	-	-
4) White	4.30	4.22	-0.08	1.30	1.12	-0.18	-	-
5) White	3.79	3.91	+0.12	1.62	0.92	-0.70	0.88	-
6) White	3.50	4.07	+0.57	1.74	0.59	-1.15	2.17	-
AVERAGE	4.10	4.38	+0.28	1.31	1.05	-0.26		

CABLE #10
012181-4c-6, 1095 Meters

FIBER IDENTIFICATION	ATTENUATION (dB/KM) BEFORE	AFTER	Δ	DISPERSION (NS/KM) BEFORE	AFTER	Δ	ATTEN. INCREASE @ -55°C FIBER	CABLE
1) Red	4.23	-	-	0.97	0.90	-0.07	2.67	-
2) White	4.61	-	-	1.35	1.40	+0.05	0.04	-
3) Blue	3.23	-	-	1.77	2.17	+0.40	5.00	-
4) White	4.57	-	-	1.40	1.33	-0.07	0.04	-
5) White	4.04	-	-	0.83	1.38	+0.55	1.58	-
6) White	4.63	-	-	0.68	1.34	+0.66	-	-
AVERAGE	4.22	-	-	1.17	1.42	+0.25		

Table 2.3-1. Polyurethane Comparison.

	Original E-80	First Modification E-80 Estane® 4054BL-4	Second Modification E-80 Estane® 4054BL-19	Estane® 58309
Durometer hardness	82A	30A	84A	85A
Ultimate tensile strength, psi	4100	4400	4000	5900
Ultimate elongation, %	735	700	700	560
Tensile modulus, psi (300%)	1100	1100	1500	1750
Tear strength, pli	480	470	515	550
Vicant softening point	+83°C	+84°C	+98°C	+101°C
Gehman freeze point	-55.5°C	-54.8°C	-48.5°C	-52°C
Gehman twist angle	165°	168°	163°	NA*
Gehman modulus of rigidity				
T_2 value	-35.5°C	-34.5°C	-32.5°C	-22°C
T_5	-41.2°C	-40.6°C	-39.5°C	-33°C
T_{10}	-44.7°C	-43.8°C	-41.0°C	-38°C
T_{50}	-53.7°C	-52.0°C	-52.5°C	-57°C
T_{100}	-75.0°C	-60.0°C	-61.0°C	NA
Melt index (+190°C, 8700 g)	15.0	30	3	35

*NA - not available.

As a quick test, the samples were subjected to high temperature impact test (+71°C) and low temperature twist-flex test (-55°C). The impact test was performed at 2.25 ft·lb (3.5 N·m) and 2.0 ft·lb (2.71 N·m). The results show that the compounds supplied could not pass both the high temperature impact test and the low temperature twist-bend test. The results are shown in Table 2.3-2. Three more compounds were supplied and tested by impact test. These samples failed the high temperature impact test as shown in Table 2.3-3.

The impact of the decision by Uniroyal Chemical to abandon the polyurethane business was felt not only in the MM&T program but in ITT's commercial business. Therefore, parallel with the efforts to solve the MM&T's polyurethane program, the Fiber Optic Cable R&D group initiated a task to evaluate polyurethane jackets. The cable construction was similar to the MM&T design except that the cable had seven fibers (the central member was an optical fiber) and the hardness of the polyurethane was 90 shore "A" approximately. The objective was to find an equivalent to Roylar® E-9B.

The compounds selected for final evaluation were

a. Estane® 58309

b. Estane® 58311

c. Roylar® E-9B (control)

Table 2.3-4 shows the performance of the three compounds.

Table 2.3-2. Estane® Evaluation.

Polyurethane	Impact Test +71°C 2.25 ft·lb # Passed/ # Tested	Impact Test +71°C 2.0 ft·lb # Passed/ # Tested	Twist-Bend -55°C # Passed/ # Tested
A. Estane® 4054BL-19	0/6	3/6	0/3
B. Estane® 4054BL-4	0/6	0/6	3/3

Table 2.3-3. Impact Test.

Lot	Room Temp (200 at 2.75 ft·lb)	+71°C (100 impacts at 2.25 ft·lb)
5880 Lubricated surface	Pass	Fail
5880 Lot 130-6-11	Pass	Marginal
5881 Nonlubricated surface	Pass	Fail

Table 2.3-4. Jacket Evaluation.

Cable Jacket Material	Twist-Bend # Passed/# Tested			Bend # Passed/# Tested			Impact # Passed/# Tested		
	-55°C	Room Temp	+72°C	-55°C	Room Temp	+72°C	-55°C	Room Temp	+72°C
Roylar● E-9B (# 071480-4C-1B)	1/3	3/3	Not tested	3/3	3/3	Not tested	Not tested	6/6	6/6
Estane● 58311 (# 071480-4C-1)	3/3	3/3	3/3	3/3	3/3	3/3	6/6	6/6	6/6
Estane● 58309-021 (# 082379-Z1)	3/3	3/3*	3/3	3/3	3/3	3/3	6/6	6/6	6/6
Estane● 4038 (# 082379-Z2)	0/3	3/3*	3/3	3/3	3/3	3/3	6/6	6/6	6/6

*One sample had Kevlar● bunching over in the area of the pulley during the run.

All impact tests were performed with 3 ft·lb load.

Table 2.3-5 shows the survivability of the fibers.

These tests will be repeated and a recommendation of a polyurethane jacket will be made before the confirmatory samples are constructed.

Table 2.3-5. Fiber Survivability.

Cable Jacket Material	Twist-Bend # Fibers Not Transmitting			Bend # Fibers Not Transmitting			Impact # Fibers Not Transmitting		
	-55°C	Room Temp	+72°C	-55°C	Room Temp	+72°C	-55°C	Room Temp	+72°C
Roylar● E-9B (No 071480-4C-1B) (6 fibers)	3*	0	Not tested	0	0	Not tested	Not tested	0	0
Estane● 58311 (No 071480-4C-1) (6 fibers)	0	0	0	0	0	0	0	0	0
Estane● 58309-021 (No 082379-Z1) (7 fibers)	0	0	0	0	0	0	0	9**	2***
Estane● 4038 (No 082379-Z2) (7 fibers)	3,1,2****	0	1	0	0	0	0	2*	1

*In one sample.
**At least one in each sample.
***Central fibers in two samples.
****In samples 1, 2, and 3, respectively.

2.4 Cabling Losses

The effects of cabling fibers into a bundle were evaluated by fabricating two bundles and measuring the losses before and after the cabling process. Two lengths of lay were used. Since both samples were comparable, it was concluded that cabling produced a small attenuation increase independent of length of lay. The results are shown in Table 2.4-1.

2.5 High NA Fiber Improvement

The 0.25 injection NA fiber improvement for military applications is complete. The parameters were within the following average values:

a.	Attenuation at 0.85 μm wavelength	3.73 dB/km
b.	Pulse dispersion (50%)	0.5 ns·km
c.	Fiber core diameter	50 μm ±2
d.	Fiber diameter	125 μm ±2
e.	Injection NA	0.25 ±0.01

2.5.1 Fiber Buffer Techniques

The Hytrel® buffer secondary extrusion to 0.94 mm diameter was examined to determine what effect it has on the low temperature attenuation performance. All extrusion conditions that may vary were evaluated including cooling conditions, payoff tension, extrusion Hytrel® melt temperature, extrusion line speed, tubing

Table 2.4-1. Roylar® E-80 Polyurethane Jacket.

Attenuation Increase (dB/km)

Fiber id	072380-4c-1b		265 m	7.6 cm Lay Length	
White	+0.697	+0.837	-0.094	-0.076	+0.038
White	+2.207	+2.631	-0.246	-0.565	-0.259
White	+2.164	+2.582	+0.125	-0.179	+0.111
White	+0.664	+0.898	-0.047	-0.079	-0.032
Red	+0.597	+1.045	-0.018	+0.125	+0.036
Red	*	*	*	*	*

Fiber id	072380-4c-1a		225 m	5.1 cm Lay Length	
White	+0.789	+1.444	-0.323	-0.340	-0.120
White	+0.538	+0.679	-0.061	+0.046	+0.167
White	+1.726	+4.025	+0.018	+0.018	-0.018
White	+0.755	+0.932	+0.078	+0.183	+0.039
Red	+1.309	+2.034	-0.127	-0.013	+0.103
Red	+1.092	+1.768	+0.022	+0.218	-0.022
Temperature	-40°C	-55°C	+25°C	+85°C	+25°C

* Splice connection broke during test.

versus pressure extrusion, and concentricity. Each condition was normalized to standard operating conditions with only one variable changed. The results obtained are shown in Table 2.5.1-1.

Using the information obtained from this group of tests, several fibers from the development work with higher NA (0.25) were extruded to 0.94 mm diameter. The results from this group of fibers are shown in Figure 2.5.1-1.

2.6 Producibility

The producibility of the cable was evaluated by initially running the equipment with dummy bundles and applying the MM&T materials. This provided an opportunity to evaluate the operation of the equipment with each of the materials and identify any problems encountered approaching maximum run rates. The following rates were achieved satisfactorily.

2.6.1 Kevlar® Serving Line

The Kevlar® serving line was operated at 1200 m/h with uniform quality and no equipment malfunctions.

2.6.2 High Speed Strander

The high speed strander was operated at 1200 m/h. Twice during this phase the payoff bays malfunctioned causing either fiber breaks or high tensions. This problem was traced to stepper-motor

Table 2.5.1-1. Results of Fiber Buffer Techniques.

Test Condition	Effect on Low Temperature Performance
Air cooling	Considerable degradation
Payoff tension	Improvement with increased tension
Higher extrusion melt temperature	Minor degradation
Lower extrusion melt temperature	Considerable degradation
Higher line speed	Minimal improvement
Slower line speed	Considerable degradation
Tubing versus pressure extrusion	Minimal difference
Concentricity	Improvement with poor concentricity

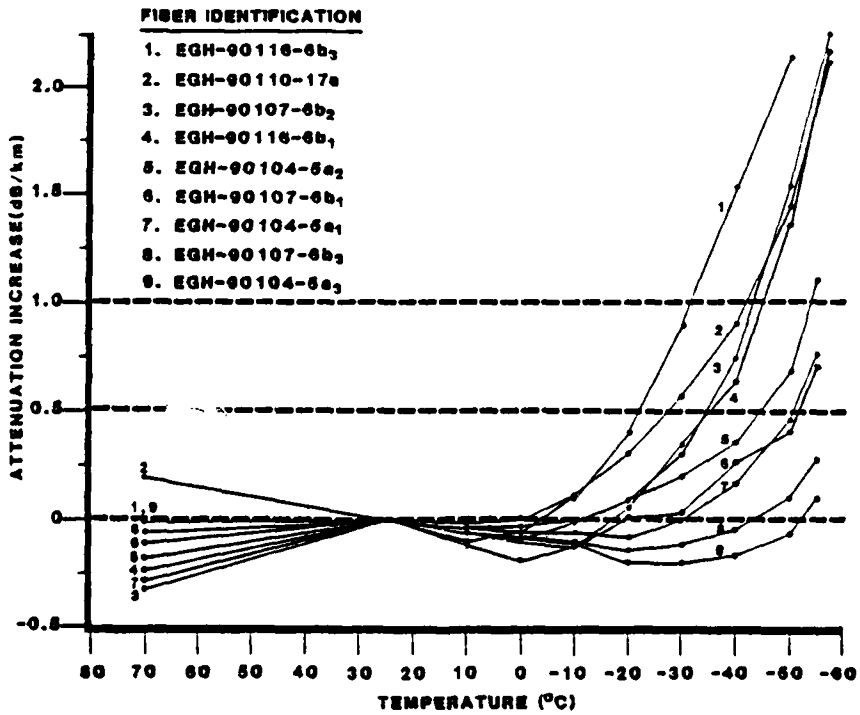

Figure 2.5.1-1. Attenuation Increase Versus Temperature of High NA (0.25) Fibers.

failures and slip-ring discontinuities. This was corrected and no further problems were encountered.

2.6.3 Final Jacket Extrusion Line

The 2.0 in extrusion line was operated at 2.2 km/h providing an excellent jacket appearance.

2.7 Test Facilities Progress

Due to a question of accuracy and repeatability of attenuation measurements according to procedure 3.1 of the Preproduction Test Procedure, an analysis of the equipment and procedure was conducted. The results of the analysis showed that the amount of power coupled out of the optical fiber and through the lenses (L_5 and L_4 in Figure 2.0 of Section I of the test procedure) into the detector was wavelength dependent, thereby making the attenuation procedure incorrect. To remedy the problem, a new detection system using a Selfoc® lens and detector was designed and built. The new detector assembly proved to be insensitive to changes in coupled power versus wavelength once the optical fiber was aligned. The preproduction test procedures are being changed to reflect the new detector assembly and attenuation measurement procedure.

3.0 SUMMARY OF GOALS AND ACCOMPLISHMENTS

The objectives and accomplishments for this period are described in the following paragraphs.

3.1 Goal: Complete Engineering Samples of Finished Cable

3.1.1 Progress

Three attempts were made, but a material supplier change and a need for high NA fiber were identified. Another attempt will be made when the evaluation of the new supplier's product (polyurethane) is complete and the high NA fiber is finished. Both are in progress.

3.2 Goal: Perform and Evaluate Cable Tests

3.2.1 Progress

Work has progressed with Goodrich to find a compound which matches the Roylar® E-80 properties. Cables have been fabricated from all the products supplied to date. (The high temperature impact test still resulted in failures.) A successful high NA fiber has been produced. Low temperature effects of fiber jacket extrusion functions have been evaluated and some beneficial handling procedures identified. Effort is required to translate these procedures into a production procedure. When this procedure and the polyurethane compounding are complete, a high degreee of confidence exists that a final cable can be fabricated.

3.3 Goal: Evaluate New Polyurethane (Estane®) Products From Goodrich

3.3.1 Progress

Three types of polyurethane have been evaluated, but high temperature impact has not been achieved. Goodrich is working on the situation.

3.4 Goal: Develop MIL-Q-9858A Procedures

3.4.1 Progress

A new detector assembly was fabricated to make attenuation measurements more accurate.

4.0 PERSONNEL

The personnel involved in this program are listed in Table 4.0-1. Due to organizational changes and the changing requirements of the program, the following changes in personnel will be effective for the remainder of the program:

a. T. Osborne replaced S. Mahurin in November 1980 as supervisor of the measurements activity.

b. R. Thompson will be replaced by R. McDevitt as manager of technical and administrative activities.

c. J. Smith will return as senior project engineer and cable development manager replacing R. Kopstein.

d. D. Taylor will assume cable production management duties as the program moves into confirmatory and pilot production phases.

e. C. Hand is assigned responsibility as project coordinator.

Resumes for R. McDevitt, T. Osborne, D. Taylor, and C. Hand are included in Appendix A.

Table 4.0-1. Personnel Working on the MM&T Program.

Name	Task	Man-Hours Expended
R. Coon	Program management	285
R. Thompson	Technical and administrative management	117
R. Kopstein	Project engineer and cable development management	271
T. Osborne	Measurements supervision	97
H. Heinzer	Measurements engineering	31
D. Taylor	Production development	116

APPENDIX A

BIOGRAPHIES of KEY PERSONNEL

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

BIOGRAPHICAL INFORMATION

NAME: F. Raymond McDevitt 1/13/81

POSITION: Director, Fiber Optics R&D and Systems

EDUCATION:

Mr. McDevitt was awarded a B.S. degree and an M.S. degree in electrical engineering from Auburn University in 1966 and 1968, respectively.

EXPERIENCE:

Mr. McDevitt has been associated with ITT Electro-Optical Products Division for 3 years. As Director of the Fiber Optics R&D and Systems Department, his responsibilities include management of all internal and contract development programs in fiber optics. In this position his duties include the management of groups performing internal and contract research and development work in the areas of light-emitting diodes/lasers, fibers, cables, couplers, and systems. Previously he served as manager of the Systems and Applications group.

RESEARCH AND DEVELOPMENT

Prior to joining ITT, Mr. McDevitt was associated with the Harris Corporation where he worked on R&D contracts at various levels for 10 years. He was a program manager of many of the company's fiber optic programs and also performed detail design, project engineering, and systems engineering tasks. He also served as a proposal engineer dealing with projects valued at up to $20 million. Mr. McDevitt and two others initiated the Fiber Optic Program at Harris in 1973.

GOVERNMENT

Mr. McDevitt worked on three Government-sponsored contracts while a graduate student at Auburn University. From 1968 to 1973 he was involved in Government R&D contracts at Harris Corporation in the areas of airborne and satellite systems. From 1973 to 1978 Mr. McDevitt participated in fiber optic military contract work at the Harris Corporation.

ADMINISTRATIVE

In his present position as Director, Fiber Optics R&D and Systems, Mr. McDevitt supervises 110 engineers and engineering aides. As group leader of the Systems area, Mr. McDevitt was in charge of 30

persons. Mr. McDevitt supervised 26 persons as section head of engineering-fiber optics at Harris Corporation. From 1975 to 1976 Mr. McDevitt supervised four persons as group leader of fiber optic advanced programs at Harris.

TECHNICAL

Mr. McDevitt's technical expertise includes broadband voice, data, and video system design, fiber optics applications engineering, R&D in fiber optics, systems engineering, and advanced programs in fiber optics. His experience includes positions as project engineer (1968-1971) on airborne data handling equipment development and systems engineer (1971-1973) on classified high data rate systems. He managed more than 15 contracts in fiber optics R&D at the Harris Corporation and served as senior technical advisor on over 13 others.

HONORS:

Mr. McDevitt has been elected to the following honor societies: Tau Beta Pi, Eta Kappa Nu, Pi Mu Epsilon, and Phi Kappa Phi.

ORGANIZATIONS:

Mr. McDevitt is a member of the Optical Society of America and is an ISSCC panel member for fiber optics. He has participated as session chairman for many fiber optics conferences including SPIE, CLEOS, and IEEE sessions.

AWARDS:

In 1969 Mr. McDevitt was presented an award from NASA for the outstanding engineering contribution of that year. He received an award for outstanding engineering leadership in fiber optics at the Harris Corporation.

PATENTS:

1. Ruby Laser Coolant.

2. VSB Digital Transmission on Fiber Optics Links, with Dr. C. R. Patisaul and Don Monteith.

PUBLICATIONS:

McDevitt, F. R. "Fiber Optic Component Standardization - Go First to the User," Electronics Magazine (October 1976).

McDevitt, F. R. "System Design Methodology for Guided Optical Communication Links," SPIE Proceedings, San Diego (1976).

McDevitt, F. R. "An FSK/FDM Multiplexed Fiber Optics System for Multichannel Asynchronous Digital Data Transmission," ITC Proceedings, Los Angeles (1976).

PUBLICATIONS (PAPERS PRESENTED AT TECHNICAL MEETINGS):

McDevitt, F. R., and E. R. Graf. "A New Criterion in the Quest for Life in Our Solar System," (1966).

McDevitt, F. R., and E. R. Graf. "A New Method for the High Accuracy Prediction of Sunspot Activity as an Aid to Deep Space Communication," (1966).

McDevitt, F. R., and C. Lavender. "Composite Transistor Designs," presented at IEEE Regional Meeting, Atlanta (1966).

McDevitt, F. R., and E. Smith. "A Computer Aided Measurement of SNR Employing a Time Interval Counter," (1966).

McDevitt, F. R. "Wideband FDM Fiber Optic Link," presented at meeting of IEEE, Williamsburg, Virginia (1975).

McDevitt, F. R. "Fiber Optic Interconnects for Instrumentation Systems," presented at Frequency Management Group Regional Meeting, Phoenix, Arizona (1976).

McDevitt, F. R., and C. R. Patisaul. "Optimized Designs for Fiber Optic Cable Television Systems," presented at meeting of IEEE CCTA, Calgary, Alberta (1977).

McDevitt, F. R., and D. Hemmings. "Some Field Applications of Fiber Optics Cable Systems," presented at 26th Wire and Cable Symposium, Cherry Hill, New Jersey (1977).

McDevitt, F. R. "CATV Trunking Cost/Performance Trades With Fiber Optics," presented at meeting of IEEE, Stevens Institute, Hoboken, New Jersey (April 1978).

McDevitt, F. R. "CATV Local Distribution and Trunking Trades With Fiber Optics," NTC, IEEE, Birmingham, Alabama (December 1978).

McDevitt, F. R. "Optical Communications Systems Design," presented at Electro-79, New York (April 1979).

PUBLICATIONS (PAPERS PRESENTED AT TECHNICAL MEETINGS) (continued):

McDevitt, F. R., J. Bowen, and T. Babcock. "Installation Results and Practical Experiences With Fiber Optic Satellite Entrance Links," presented at FOC '79, Chicago (September 1979).

McDevitt, F. R., and C. K. Kao. "Application of Fiber Optics to Multiservice Business and Home Telecommunications," presented at Communications Techniques Seminar, Princeton University (March 1980).

McDevitt, F. R., and C. K. Kao. "Application of Fiber Optics to Multiservice Business and Home Telecommunications," presented at IEEE Digital Communications Seminar," New York (June 1980).

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

BIOGRAPHICAL INFORMATION

NAME: Thomas G. Osborne 2/27/81

POSITION: Senior Project Engineer

EDUCATION:

Mr. Osborne was awarded an A.A.S. degree in electronics from DeVry Institute of Technology in 1966. He received a B.S.E.E. degree in electrical engineering from Marquette University in 1970.

EXPERIENCE:

Mr. Osborne has been associated with ITT Electro-Optical Products Division for 3 years. As a Senior Project Engineer in the Fiber Optics Laboratory his responsibilities include supervision of the design and development section of the Interface Technology Group. He also is project leader of several development engineering projects. His responsibilities also have included packaging development for LED and semiconductor light sources, detectors for fiber optic applications, and the development of fiber coupling elements for transmitter receiver modules for fiber optic communication links.

RESEARCH AND DEVELOPMENT

Prior to joining ITT, Mr. Osborne was associated with Spectrum Control, Inc., Fairview, Pennsylvania, as product engineering manager. In this capacity he was responsible for the electrical and mechanical design of hermetic seal and resin seal emi-rfi filters. Prior to his service with Spectrum Control, Mr. Osborne was associated with the Allen-Bradley Co., Milwaukee, Wisconsin, as development engineer. His duties included the electronic and mechanical design of hermetic seal emi-rfi filters.

ADMINISTRATIVE

While with Spectrum Control, Mr. Osborne directed the work of two engineers and two technicians. He was a member of the company's management steering committee and project review committee.

TECHNICAL

Mr. Osborne's technical expertise includes the following areas: electrical and mechanical properties of multilayer monolithic ceramic capacitors. various metals, conductive epoxies, and epoxy potting compounds; soldering of metal-to-metal coated glass and

metallized ceramic capacitors forming hermetic and nonhermetic seals; diffusion work on large scale integrated circuits, and electrical and physical failure analysis of large scale integrated circuits.

ORGANIZATIONS:

Mr. Osborne is a member of Eta Kappa Nu.

PUBLICATIONS (PAPERS PRESENTED AT TECHNICAL MEETINGS):

McDuffee, F. T., T. G. Osborne, and G. W. Bickel. "Techniques To Overcome Failure Mechanisms in Optical Fiber Splices," to be presented at the Third International Conference on Integrated Optics and Optical Fiber Communication (April 1981).

ITT ELECTRO-OPTICAL PRODUCTS DIVISION
BIOGRAPHICAL INFORMATION

NAME: Donald L. Taylor 2/13/81

POSITION: Cable Engineer

EDUCATION:

Mr. Taylor received an A.S. degree in engineering from Virginia Western Community College in 1974. He attended Virginia Polytechnic Institute and State University in 1975 and is currently enrolled at Radford University as a B.S. degree candidate in chemistry.

EXPERIENCE:

Mr. Taylor has been associated with ITT Electro-Optical Products Division for 6 years. As a Cable Engineer in the Fiber Optics Laboratory, he is currently involved in the development of processing techniques and fiber optic cable fabrication for military and commercial R&D contracts. He is also responsible for the supervision of engineering aides working on internally funded R&D efforts.

Prior to assuming his present position, Mr. Taylor was supervisor of the ITT EOPD Fiber Optic Cable Production Department. His duties included the organization and scheduling of fiber optic cable production and improvement of cable production efficiency. In addition, he coordinated the use of equipment for research and development, assisted engineers in development activities, and procured materials for R&D.

ADMINISTRATIVE

As Cable Engineer, Mr. Taylor supervises four engineering aides. He also is in charge of cable manufacturing for the R&D cabling group.

MANUFACTURING

Mr. Taylor's manufacturing experience includes cable fabrication processes such as extrusion, various stranding techniques, and precision coiling.

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

BIOGRAPHICAL INFORMATION

NAME: Charles R. Hand 2/17/81

POSITION: Project Engineer

EDUCATION:

Mr. Hand was awarded a B.S. degree in physics from the University of Washington in 1969. He has taken postgraduate courses in applied physics at the same university.

EXPERIENCE:

Mr. Hand joined ITT Electro-Optical Products Division in November 1980. As Project Engineer in the Fiber Optics Laboratory his responsibilities include management of contract performance and monitoring of technical and cost compliance, standard products, and process documentation.

RESEARCH AND DEVELOPMENT

Prior to joining ITT Mr. Hand was associated with Boeing Aerospace Corporation from 1967 to 1980 as senior engineer. Mr. Hand was involved in the development of a system of computer programs to generate engineering drawings, etc., for cabling. Concurrently he served in a consulting capacity in the production stage of a Naval Oceans Systems Center (NOSC) contract to demonstrate high production rate fiber optic cabling.

Other duties performed by Mr. Hand at Boeing included writing fiber optic cabling and fabrication procedures for the NOSC contract (1977-1979); developing parts standards for components to be used in a Boeing developed optic link and installation procedures for aircraft (1976-1977); conducting flight essential avionics unit qualification tests (1974-1976); cabling fabrication, component, and installation design (1972-1974); and evaluating electrical cabling components and installation and writing procurement and assembly procedures (1967-1972).

ADMINISTRATIVE

While associated with Boeing Mr. Hand supervised groups of two to eight persons from 1972 to 1980.

TECHNICAL

Mr. Hand's technical expertise includes cabling materials evaluation and test procedure analysis, thermal distribution analysis and power system design, electronic system functional and environmental testing, FORTRAN programming, software system

analysis, explosive vapors and testing of the vapors, and digital systems function analysis and troubleshooting.

ORGANIZATIONS:

Mr. Hand is a member of the Seattle Professional Engineering Employees Association advisory council on energy uses.

PUBLICATIONS (PAPERS PRESENTED AT TECHNICAL MEETINGS):

Hand, C. R. "Critical Electronics and Electronics System Separation," Boeing (Jul 16, 1969).

Hand, C. R. "Sizing New Generation Aircraft Wire and Circuit Breakers," National Aerospace and Electronics Conference, Boeing (Oct 4, 1972).

Hand, C. R. "Process Document for Fabrication of Tubular Wire Braid," Boeing (Oct 11, 1974).

Hand, C. R. "Blindside Connector Design," Boeing (Sep 25, 1975).

Hand, C. R. "Evaluation Test Report - E-3A Accessory Box Assemblies," Boeing (Jan 30, 1976).

Hand, C. R. "Explosive Vapor Testing of Air Vehicle System Components (Procedure)," Boeing (Mar 4, 1976).

Hand, C. R. "NOSC Technical Report 340: Airborne Fiber Optics Manufacturing Technology, Aircraft Installation Processes," (Oct 24, 1978).

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